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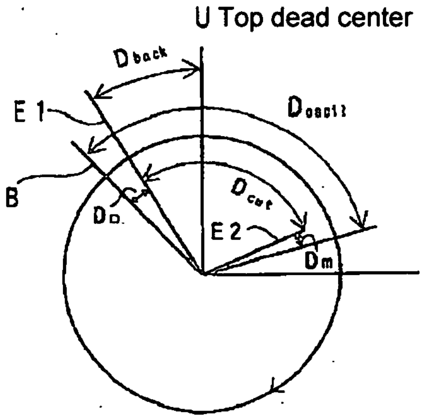
(54) (Title of Invention) Tufting Machine

(57) (Abstract)
(Problem to be Solved)
To provide a tufting machine capable of cutting pile yarn with high reliability.

(Means of Solution)

This tufting machine is composed of a needle interlocked with a motor, a looper interlocked with the motor, a knife interlocked with the motor and cutting a pile yarn engaged with the looper in the 1st rotational angle range D_{cut} of the motor and a yarn-cut controlling means to cut the pile yarn engaged with the looper at the end of the sewing of the pile yarn by rotating the motor in normal and reverse directions within the 2nd rotational angle range D_{oscil} including the 1st rotational angle range D_{cut}.



(Scope of Claims)

(Claim 1)
[Translation of Claim 1 through Claim 16 omitted.]

(Detailed Explanation of the Invention)

(0001)
(Industrial Field of Application)
This invention relates to a tufting machine. More specifically, it relates to improvements in a mechanism for automatically cutting pile yarn engaged with looper after completion of sewing in a tufting machine that sews pile yarns in base material of carpets, mats, and so on.

(0002)
(Prior Art)
Tufting machines equipped with mechanisms to automatically cut pile yarn have been published, for example, Patent Publication [Kokai] No. 3-22312. In these conventional tufting machines, needles are stopped once at top dead center after tufting yarn sewing operations have been completed. After that, motor is rotated forward 90 degrees, then reverse 90 degrees. Tufting yarns engaged with looper are cut by knife as this forward and reverse rotation is repeated 3 to 4 times.

(0003)
(Problems that the Invention is to Solve)

Although the aforementioned composition tufting machines certainly are able to automatically cut tufting yarn, the inventors [of this invention] found that reliability of cutting operations was inadequate upon investigation. Namely, there were instances in which yarn engaged with looper could not be completely cut even if the aforementioned cutting operation was performed. In those cases, the remaining pile yarn had to be cut manually.

(0004)
With that, the inventors of this invention made further diligent investigations for cutting pile yarn with high reliability. As a result, they noticed that motor rotational angle range, in other words forward rotation to a 90° range from needle top dead center, did not always match the motor rotational angle at which yarn was cut by knife (1st rotation angle range). For example, as shown in Figure 1, in a tufting machine (Model No.: MC Series) supplied by Murakoshi Sewing Machine Ind. Co., Ltd. (one of the applicants of this invention), motor rotational range D_{cut}, at which yarn is cut by knife, extends to the front and back of angle U which corresponds to needle top dead center (1st angle). Consequently, when the aforementioned conventional technology is applied, the knife does not operate in the reverse-direction angle range D_{back} from top dead center angle U. Thus, the knife is not fully executing its primary function. This is believed to be the cause of incomplete yarn cutting.

(0005)
Therefore, the purpose of this invention is for the inventors to solve the problems newly discovered above by providing a tufting machine capable of cutting pile yarn with high reliability.

(0006)
(Means of Solving the Problems)
The tufting machine in this invention has the following composition to achieve the aforementioned purpose. That is to say, it is a tufting machine composed of a needle interlocked with a motor, a looper interlocked with the motor, a knife interlocked with the motor and cutting a pile yarn engaged with the looper in the 1st rotational angle range D_{cut} of the motor and a yarn-cut controlling means to cut the pile yarn engaged with the looper at the end of the sewing of the pile yarn by rotating the motor in forward and reverse directions within the 2nd rotational angle range D_{oscil} including the 1st rotational angle range D_{cut}.

(0007)
As explained while referring to Figure 1, the motor of the tufting machine composed in this way is operated forward and reverse in the 2nd rotational angle range D_{oscil} when pile yarn sewing has been completed. By doing this, the 1st rotational angle range D_{cut}, which is included in the 2nd rotational angle range D_{oscil}, is always executed. In other words, the motor rotates forward and reverse in this 1st rotational angle range D_{cut}. Therefore, the knife fully executes its primary function. Thus, pile yarn engaged with the looper will be reliably cut.

(0008)
The motor outputs the necessary torque to sew pile yarn in base material, and there are no particular limitations as long as switching between forward and reverse is done smoothly, but in general, a servomotor can be used. Motor rotational angle is measured by an encoder attached to the motor. Needle, looper and knife are interlinked with motor via commonly known mechanisms. The tufting machine is equipped with these various sets of items. Needle top dead center becomes the datum for tufting machine operation. Therefore, to check top dead center position, the upper shaft status of the tufting machine is monitored, for example. In terms of monitoring method, the commonly known method of using a light sensor can be applied.

(0009)
The 1st rotational angle range D_{cut} will vary depending on tufting machine type, and the relative position and operational relationship between knife and looper in particular. There are cases in which top dead center angle U is not included in the 1st rotational angle range D_{cut}. To eliminate wasteful operation of the tufting machine, the 2nd rotational angle range D_{oscil} is made consistent with the 1st rotational angle range D_{cut}. It is desirable to set the margin Dm between 1st rotational angle range D_{cut} and 2nd rotational angle range D_{oscil} at 0 to 10 degrees.

(0010)
As shown in the example in Figure 1, it would also be conceivable to apply the aforementioned conventional technology when angle U corresponding to needle top dead center is included in the 1st rotational angle range D_{cut}. In that case, the needle is first stopped at the 1st edge E1 of the 1st rotational angle range D_{cut}, then forward from there to the 2nd edge E2, then reversed to the 1st edge E1 (this is repeated). However, when the motor is stopped at the 1st edge E1 the needle is lowered from top dead center. Therefore, the gap between stopped needle and base material narrows and it becomes difficult to handle the base material. In addition, when the gap between needle and base material narrows, needless restrictions will end up being applied to pile length and/or base material thickness in order to ensure the required margin between needle and base material for handling of base material at the start and completion of sewing.

(0011)
To solve these problems, the second aspect of this invention, a yarn cutting control means, stops the motor at 1st angle U to stop the needle at top dead center, then repeatedly forward and reverse in the 2nd rotational angle range D_{oscil}.

(0012)
Due to the second aspect of this invention composed in this way, it becomes easy to handle the base material during pile yarn cutting because the needle stops once at top dead center.

(0013)
Moreover, by making the needle return to top dead center after pile yarn cutting is completed, it becomes easy to handle the base material even after yarn cutting operations

have been completed. Also, by always setting needle stop position at top dead center in this way, needless restrictions will no longer be applied to pile length and/or base material thickness.

(0014)
In the aforementioned first aspect, the goal was reliable cutting of pile yarn by knife when the motor is rotated in 2nd rotational angle range D_{oscil} after pile yarn sewing is completed. The purpose of the third aspect of this invention is to even more reliably cut pile yarn.

(0015)
Namely, in the third aspect of this invention, the first aspect of the invention is executed and the motor is operated forward and reverse in the 2nd rotational angle range D_{oscil} after pile yarn sewing is completed. If yarn is not completely cut even after this operation, the motor is once again operated forward and reverse in the 2nd rotational angle range D_{oscil}. The 1st yarn cutting operation and the 2nd yarn cutting operation are both performed by inputting the same yarn cut command signal into the tufting machine's control device. In the working example, the yarn cut command is input by stepping on a foot-operated switch, stepping in a direction opposite of that used during sewing operations. In this way, by repeating the yarn cutting operation, pile yarn will be more reliably cut.

(0016)
There is no particular limit to the number of times that motor forward and reverse is repeated in the 1st yarn cutting operation and 2nd yarn cutting operation. From the perspective of ease of control, it is desirable to have the number of repetitions be the same for both. In order to make yarn cutting reliability even higher, the number of repetitions in the 2nd operation could be more than in the 1st operation.

(0017)
In ordinary tufting machines, a yarn loosening device of commonly known structure is operated before the 1st yarn cutting operation to forcibly feed yarn out from the bobbin, slacken the yarn, and prevent the yarn from coming out of needle after yarn is cut. When this yarn loosening operation is performed before the 2nd and later yarn cutting operations, when the yarn engaged at the front end of looper after the 1st yarn cutting operation is cut, in other words the yarn that has just passed through the tufting needle is cut, there is a concern that this yarn on the tufting needle side will get pulled back and slip out of the tufting needle.

(0018)
Thus, based on the 4th aspect of the invention, a yarn loosening device similar to a conventional one is operated during the 1st yarn cutting operation, but the yarn loosening device is stopped for 2nd and later yarn cutting operations. Doing this prevents yarn from slipping out of tufting needle.

(0019)

Next is an explanation of the 5th aspect of the invention. The 5th aspect of the invention is related to starting up a tufting machine for thick base material, and the purpose of the 5th aspect is to prevent motor lockup beforehand by maximizing the use of motor driving power.

(0020)
Conventionally, machines have been disclosed, for example Public Patent Disclosure Bulletin [Kokai] No. 2-119895, that reverse the motor, gather momentum, and insert the needle one more time when the time for the first 1 needle to begin sewing exceeds a preset time. However, there is a concern that motor lockup may be unavoidable when a large initial load is applied to motor, depending on types of base material and needle.

(0021)
This is the problem that the 5th aspect of this invention solves. Namely, it is a tufting machine composed of a needle interlinked with motor, a means of detecting torque in the motor, and a means of control to control the motor by reversing to a specific angle once and removing the needle from the base material if the motor torque exceeds a preset threshold value when needle pierces base material.

(0022)
Based on the tufting machine composed in this way, motor torque is monitored, and therefore motor lockup can be more reliably prevented than in the conventional example that only monitors time.

(0023)
Motor torque is computed and determined in a commonly known way using a feedback value of electric current flowing in the motor. Torque threshold and time can be set as needed to suit the purposes of motor and sewing operations. In the working example, torque threshold was set at 9.8 N·m and time was set at 0.8 seconds. In the aforementioned, it is also acceptable to use motor revolutions instead of motor torque as the subject of detection. In this case, when motor rpm is smaller than a specific threshold (35 rpm for example) and that condition continues for a specific time (0.8 seconds for example), the motor is reversed to a specific angle once, needle removed from base material, and then the motor is rotated forward to try inserting needle into base material. Motor rpm is determined by an encoder attached to machine shaft or motor shaft. In addition, based on a needle position sensor to detect tufting needle that has gone through base material, if tufting needle that has gone through cloth while machine is running has not been detected for a specific time or more (2.2 for example), the motor is reversed to a specific angle once, then rotated forward to try inserting needle into base material.

(0024)
(Working Example of the Invention)
The workings of this invention will be explained based on the working example below. Figure 2 shows the structure of the working example tufting machine. In Figure 2, 1 is a tufting machine unit, 2 is a motor, 3 is a needle detection sensor that detects the position of needle 21 of the tufting machine unit 1. 4 is a tufting pulley and 5 is a motor pulley to

transmit motor 2 rotation to tufting machine unit 1. 7 is a stator of motor 2, 8 is a rotor of motor 2, and 9 is a brake to stop motor 2. 10 is a foot pedal to operate tufting machine unit 1, 11 is a lever unit to detect operation of foot pedal 10, 12 is a main control circuit that controls the tufting machine unit overall, and 13 is a motor driver that controls the rotational speed and rotational direction of motor 2.

(0025)
Number 20 in the figure is a yarn loosening device located between tufting needle 21 and bobbin 23. This yarn loosening device 21 lever operation loosens yarn 25 after tufting yarn 25 sewing operation is completed and before tufting yarn 25 is cut, and releases tension on tufting yarn 25 passing through needle 25 [sic, should be 21] so that it does not slip out of needle 21.

(0026)
Number 30 in the figure is a torque sensor. In the working example, an ammeter is used as the torque sensor. The value of stator 7 electric current detected by this ammeter is sent to main control device 12, and the value of electric current detected is processed by a program pre-saved in a CPU not shown in the figure to determine the present torque of motor 2.

(0027)
An input device 40 is connected to main control device 12. This input device 40 has buttons, a 10-key pad and so on not shown in the figure, and through the operation of these, parameters that regulate tufting machine unit 1 operation (tuft length, spacing and so on) can be input. In addition, motor rotational angle range (2nd rotational angle range) for yarn cutting operations and the number of times [cycles] of forward and reverse operations can also be input.

(0028)
The main control device 12 is composed of elements that comprise a microcomputer not shown in the figure, such as a CPU, ROM, RAM, and I/O board. Main control programs are saved in ROM, and the CPU controls devices overall based on these programs. The various parameters input by operators are saved in RAM. The following are included in these parameters: motor rotational angle range in thread cutting operation (2nd rotational angle range), the number of times of forward and reverse operations, torque threshold Tth at motor startup and reference time passing TMref after torque threshold is exceeded until motor is reversed. Motor driver 13 has an inverter that controls direction of motor rotation by phase switching.

(0029)
Figure 3 shows the condition of tufting yarn 25 being sewn to base material. Tufting yarn 25 is carried through base material 27 by needle 21, engaged with looper 28, and cut by knife 29. Number 50 is a motor-driven crank mechanism, and the needle is mechanically interlinked with motor and moved up and down via this crank mechanism. Looper 28 and knife 29 are also mechanically interlinked with motor 2 and oscillate via commonly known crank mechanisms not shown in the figure. The positions of the needle 21, looper

28 and knife 29 are regulated based on motor 2 rotational angle. As shown in Figure 1, knife 29 interferes with looper 28 and cuts yarn 25 at the 1st rotational angle range D_{cut}.

(0030)
During yarn cutting operations, needle 21 is in stopped condition and the base material 27 is freed after a base material pressing device not shown in the figure is raised, then while this [base material] is lightly pulled, only knife 29 is operated, coming into interference with looper 28 and cutting tufing yarn 25. Since there are usually 2-3 yarn loops engaged with the looper 28, it is desirable to repeat motor 2 forward and reverse motion and have knife interfere with looper several times to cut all these yarns.

(0031)
Returning to Figure 2, S1 in the figure is a sewing start signal, S2 is a yarn cut command signal, S3 is a needle up signal, VC is a speed command signal, SRT is an operation signal, BK is a brake signal, SST is a stop signal, and R is a reverse command signal. Sewing start signal S1 and yarn cut command signal S2 are signals input from lever unit 11 to main control device 12. Speed command signal VC is a signal input from lever unit 11 to motor driver 13. Operation signal SRT, brake signal BK, stop signal SST, and reverse signal R are command signals input from main control device 12 to electric motor speed control circuit 13.

(0032)
The working example tufting machine is comprised as described above. Its operation will be explained next. Figure 4 shows an operation timing chart. Sewing start signal S1 turns on by pressing foot pedal 10, operation signal SRT is output from main control device 12 to motor driver 13, motor 2 stator 7 is excited, rotator 8 is rotated and tufting machine unit 1 is driven by motor pulley 5, belt 6 and machine pulley 4.

(0033)
Next, by changing the amount of pressing on foot pedal 10, voltage and/or current and/or frequency applied to stator 7 of motor 2 is controlled based on speed command signal VC of lever unit 11 and position detection signal FG of needle position sensor 3 attached to tufting machine unit 1, and thus motor 2 rpm is controlled at a desired speed corresponding to the amount that foot pedal 10 is pressed.

(0034)
Also, when foot pedal is returned to neutral position, a low speed command signal LLKO for position locating is output from main control device 12, and at the same time, tufting machine unit 1 needle up or needle down is detected based on the position locating signal (UP or DN) of needle position sensor 3, and electromagnetic brake 8 is excited to stop the drive of tufting machine unit 1.

(0035)
Furthermore, in a condition where foot pedal 10 is kicked back, in other words rotated in the opposite direction of press-down direction, main control device 12 first outputs a stop signal SST to motor driver 13 to stop motor 2. At this time, main control device 12

controls motor 2 through motor driver 3 so that needle 21 stops at top dead center based on needle position locating sensor 3 detection signal. After that, yarn cut command signal S2 is output and tufting yarn 25 is cut.

(0036)
Figure 5 is a flow chart that shows the working example tufting machine's functions that prevent motor 2 from locking. It is particularly effective when processing thick base material 27. The operations shown in this flow chart are performed by the various elements of the tufting machine based on pre-set programs in main control device 12.

(0037)
The present torque Tmo of motor 2 is detected in Step 1. This torque Tmo is determined by processing the value of electric current impressed on stator 7. Next, in Step 3, the obtained present torque Tmo of motor is compared with preset threshold torque Tth. An operator can use input device 40 to set this threshold torque Tth as desired. Of course, it is needless to say that certain restrictions should be placed on settable threshold torque Tth from the perspective of preventing motor 2 lockup. In the working example tufting machine, the factory preset value [value at shipping] of threshold torque Tth was set at an initial value of 9.8 N·m. If motor 2 torque is less than or equal to threshold torque Tth (Step 3: Y), sewing operations continue as is (Step 5). If motor 2 torque exceeds threshold torque Tth (Step 3: N), we proceed to Step 7 and the time passing TMd since motor 2 torque Tmo exceeded threshold torque Tth is measured.

(0038)
In Step 9, time passing TMd is compared to preset reference time passing TMref. An operator can use input device 40 to input this reference time passing TMref as desired. Of course, it is needless to say that certain restrictions should be placed on settable reference time passing TMref from the perspective of preventing motor 2 lockup. In the working example tufting machine, the factory preset value of reference time passing TMref was set at a level of 0.8 seconds. If measured time passing TMd is less than or equal to reference time passing TMref (Step 9: Y), we return to Step 1. If measured time passing TMd exceeds reference time passing TMref (Step 9: N), we proceed to Step 11. In this case, it means that a large load has been applied to motor 2 for a long time as needle 21 has not gone through base material 27.

(0039)
Step 11 determines whether the number of times tried exceeds a preset number of times n. Here, a try means the operation performed in Step 17, where motor 2 is reversed to a specific angle once, momentum gathered, and needle 21 thrust into base material 27. An operator can use input device 40 to input this number of times n too. In the working example tufting machine, the factory preset number of times was 3 times.

(0040)
In Step 11, if the number of times tried is less than or equal to the designated number of times n (Step 11: Y), we proceed to Step 15, motor 2 is reversed to a specific angle once, momentum gathered, then rotated forward. At this time, a counter not shown in the figure

operates to increase the number of times tried by 1. Then this number of times tried is compared with the preset number of times n in Step 11.

(0041)
Motor lockup will occur when a large load is applied to motor 2 and that condition continues for a long time. Therefore, in this working example the load applied to motor 2 is monitored by comparing motor 2 torque Tmo to threshold torque Tth, and in addition, the time that a large load has been applied to motor 2 is monitored by comparing the time passing TMd since motor 2 torque Tmo exceeded threshold torque Tth. In this way, motor 2 lockup can be reliably prevented beforehand by checking motor condition using two parameters.

(0042)
In Step 11, if the number of times tried exceeds the designated number of times n (Step 11: N), it is judged that it will be difficult for needle 21 to go through base material 27 even if more retries are repeated, and sewing operations are suspended (Step 13).

(0043)
The above operations are particularly appropriate to use at tufting machine startup, but they can also be performed at specific intervals while the tufting machine is running and be used as functions that support emergency stop of the tufting machine during emergencies or other situations.

(0044)
Next, operations during yarn cutting will be explained while referring to the time chart in Figure 6. When foot pedal 10 is kicked back to turn the first yarn cut signal on, yarn loosening device 20 operates and tension on tufting yarn 25 is released. Next, simultaneous with completion of yarn loosening device 20 operations, a base material pressing device not shown in the figure is raised (it also presses down on base material 27 during sewing operations) so that it is possible to pull out base material 27. Once a stop signal is input and motor 2 stops, motor 2 angle is an angle (1st angle) corresponding to needle 21 top dead center.

(0045)
At the same time that the base material pressing device is raised, motor 2 reverses once from 1st angle U to the reverse edge angle B of the 2nd rotational angle range D_{oscil} shown in Figure 1. Next, motor movement is repeated forward and reverse in the 2nd rotational angle range D_{oscil}. Then, yarn cut command signal is turned off when foot pedal 10 returns to neutral. Next, after forward and reverse is performed two times, motor proceeds forward and stops at 1st angle U. The interference of looper 28 and knife 29 and cutting of tufting yarn 25 engaged with looper 28 occurs in motor 2 1st rotational angle range D_{cut}. In this working example tufting machine this angle range D_{cut} is included in motor 2 rotational angle range (2nd rotational angle range) D_{oscil} of yarn cutting operations. Therefore, knife 29 fully performs its primary job through the execution of yarn cutting operations in the working example. Thus, tufting yarn 25 engaged with

looper 28 is reliably cut. Also, in the working example, the margin D_m between 1st rotational angle range D_{cut} and 2nd rotational angle range D_{oscil} was essentially 0 degrees.

(0046)
In the working example, motor 2 makes two round trips and is finished based on the timing of the yarn cut command signal turning off, however, the number of times that motor 2 rotates forward and reverse is not limited to this. Any desired the number of times can be set by an operator using input device 40. In addition, the number of times of motor 2 forward and reverse rotation can also be controlled by yarn cut command signal input timing.

(0047)
If tufting yarn 25 engaged with looper 28 could not be completely cut in the 1st cutting operation explained above, the foot pedal 10 is kicked back again to input the 2nd yarn cut command signal. As shown in Figure 6, at this time, the operations of all elements excluding yarn loosening device 20 are the same as the 1st yarn cutting operations. Yarn loosening device 20 is stopped due to a concern that tufting yarn 25 may slip out of tufting needle 21 if the yarn loosening device 20 is operated since tufting yarn 25 was already sufficiently loosened in the 1st operation of the yarn loosening device 20.

(0048)
(Effects of the Invention)
As explained above, the tufting machine of this invention is composed of a needle interlocked with a motor, a looper interlocked with the motor, a knife interlocked with the motor and cutting a pile yarn engaged with the looper in the 1st rotational angle range D_{cut} of the motor and a yarn-cut controlling means to cut the pile yarn engaged with the looper at the end of the sewing of the pile yarn by rotating the motor in normal and reverse directions within the 2nd rotational angle range D_{oscil} including the 1st rotational angle range D_{cut}.

(0049)
Due to the tufting machine composed in this manner, by rotating the motor 2 forward and reverse in the 2nd rotational angle range D_{oscil}, the 1st rotational angle range D_{cut}, which is included in the 2nd rotational angle range D_{oscil}, is always executed. In other words, the motor moves forward and backward in this 1st rotational angle range D_{cut}. Therefore, the knife will fully perform its primary function. Thus, the pile yarn engaged with looper will be reliably cut.

(Brief Explanation of Drawings)

(Figure 1) Figure 1 is an explanatory figure that shows motor operations of the working example tufting machine of this invention.

(Figure 2)
Figure 2 is a block diagram of the same tufting machine.

(Figure 3)
Figure 3 is a drawing that shows the condition of tufting yarn sewing with respect to base material.

(Figure 4)
Figure 4 is a timing chart the shows sewing operations of the same tufting machine.

(Figure 5)
Figure 5 is a flow chart that shows functions that prevent motor lockup of the same tufting machine.

(Figure 6)
Figure 6 is a timing chart that shows yarn cutting operations of the same tufting machine.

(Legend)

1	Tufting machine unit
2	Motor
3	Needle position sensor
7	Stator
8	Rotor
9	Brake
10	Foot pedal
11	Lever unit
20	Yarn loosening device
21	Tufting needle
25	Tufting yarn
27	Base material
28	Looper
29	Knife
40	Input device
50	Crank mechanism

Figure 1

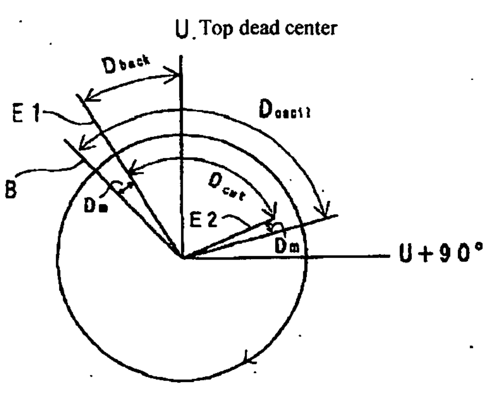


Figure 2

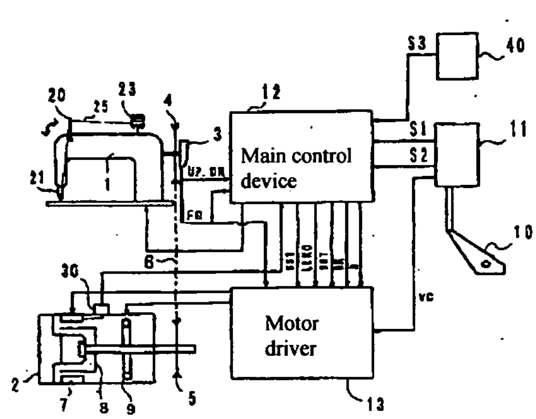


Figure 3

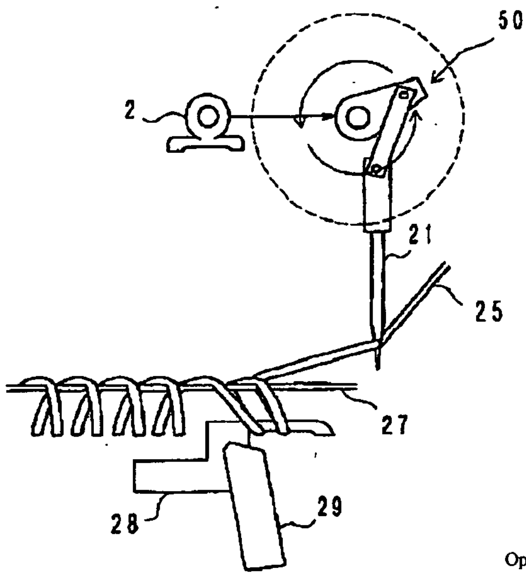


Figure 4

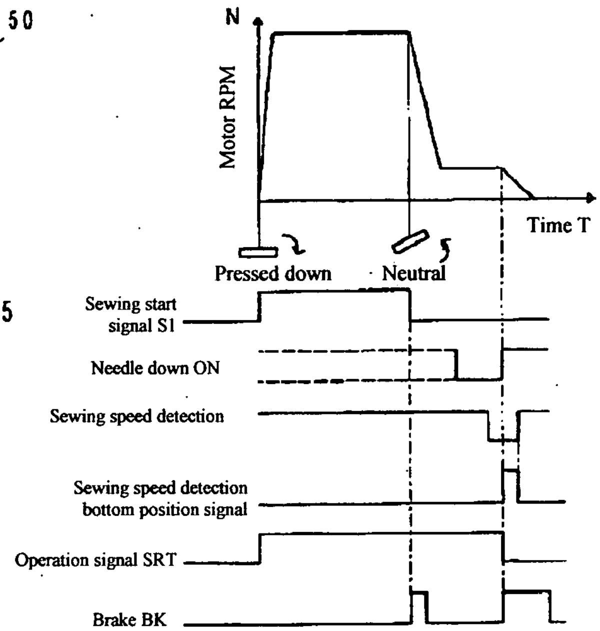


Figure 5

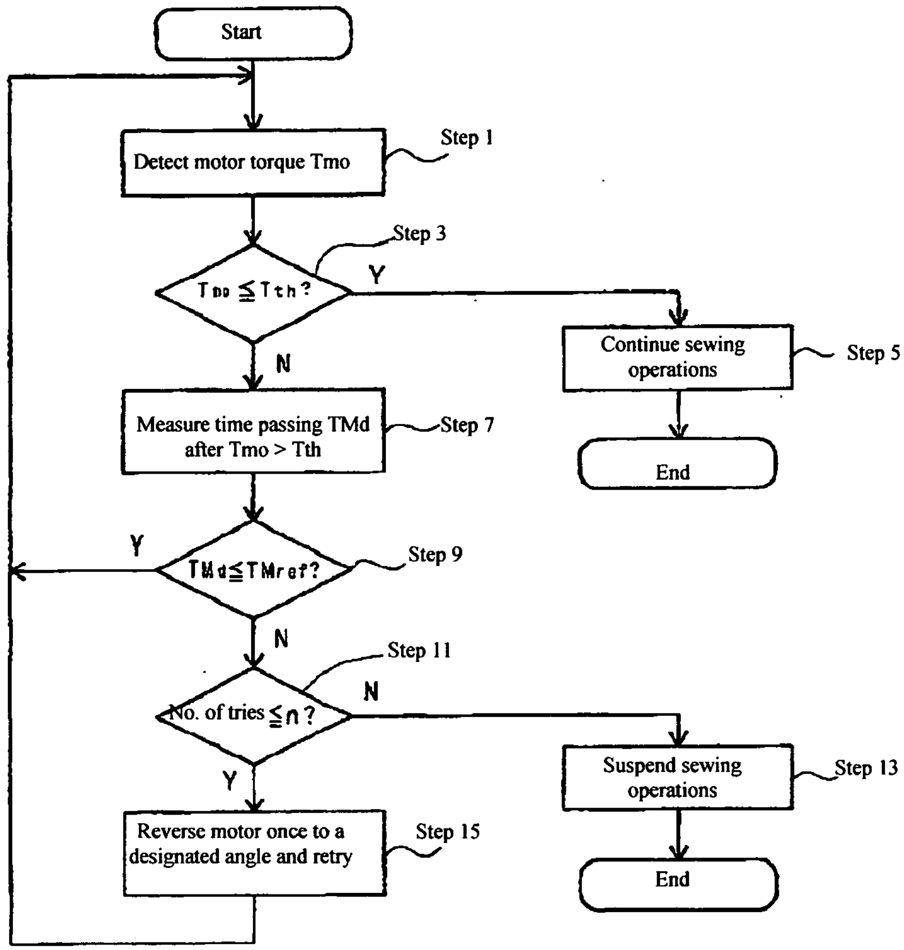
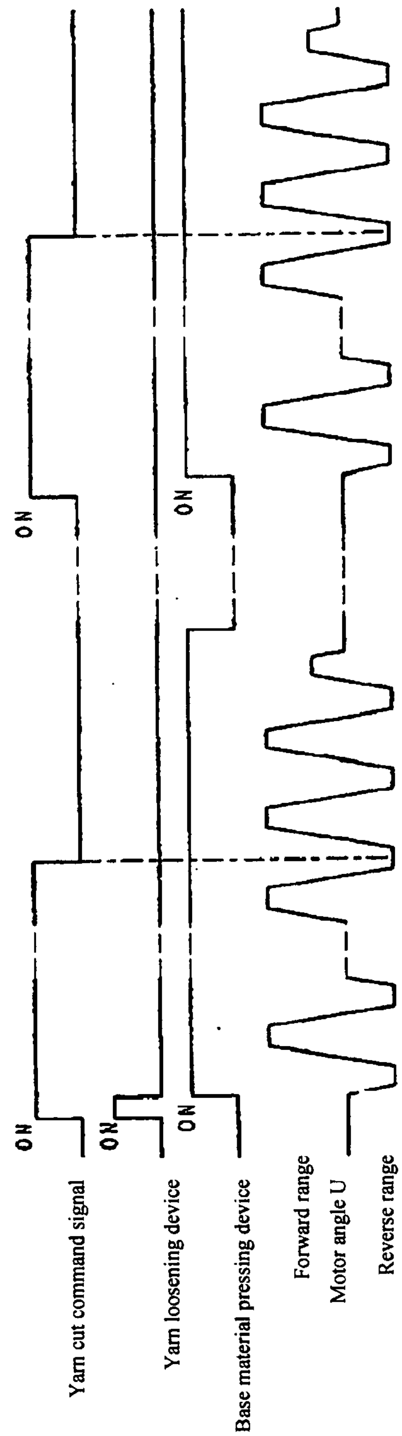

Start
Detect motor torque Tmo
Step 1
Step 3
Tmo ≦ Tth?
Y
N
Continue sewing operations
Step 5
End
Measure time passing TMd after Tmo > Tth
Step 7
Y
TMd≦TMref?
Step 9
N
Step 11
No. of tries ≦ n ?
N
Y
Suspend sewing operations
Step 13
End
Reverse motor once to a designated angle and retry
Step 15

Figure 6


Yarn cut command signal
Yarn loosening device
Base material pressing device
Forward range
Motor angle U
Reverse range
ON
ON
ON
ON
ON

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